DEVELOPMENT OF THE MALE GONOPODS AND LIFE HISTORY STUDIES OF A POLYDESMID MILLIPEDE.*

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INTRODUCTION

The gonopod of the male millipede is at present the chief diagnostic character in identifying species. Therefore the development of these structures is interesting and important in the study of the millipede group.

For a study of this development *Euryurus erythropygus* (Brandt), a Polydesmid millipede, was chosen because they were found in abundance and thrived in the laboratory.

Since so little is known regarding the life-history and habits of the Polydesmidae or of the millipedes in general, opportunity was taken to study certain anatomical features; copulation; oviposition; characteristics of the eggs and the post-embryonic development. With regard to the latter the instars in the life-history were determined; studies made of ecdyses and of the cocoons. The cocoons are hollow, somewhat spherical chambers in which ecdyses of the instars occurs.

The research upon which this report is based was carried on chiefly at Miami University, Oxford, Ohio, during the school year 1924–1925. Observations were continued at The Lake Laboratory, Put-in-Bay, Ohio, and at The Ohio State University.

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MATERIALS AND METHODS

While collecting Myriapods in Ohio, near Oxford, during the latter part of September and in October, 1924, it was observed that specimens of *Euryurus* were abundant in the

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heartwood of much decayed logs, in moist and more decayed wood, usually sapwood, and under decaying wood if rather moist conditions prevailed. With a hope that they would breed and endure captivity in the laboratory, the specimens collected were placed in glass receptacles approximately five and one-half inches in diameter and three and one-eighth inches deep. These were half filled with small broken up pieces of moist and much decayed sapwood from an old rotten log and a little humus. A layer of vaseline was spread around the rims of the receptacles and glass covers placed over them,

TABLE I.

STAGES FOUND, MEAN MEASUREMENTS OF WIDTH AND LENGTH OF THREE INDIVIDUALS OF EACH STAGE, NUMBER OF SEGMENTS AND PAIRS OF LIMBS ON EACH SEGMENT.

Stages	Number of Segments	Number of Pairs of Legs		Length in Millimeters	Width in Millimeters
		Male	Female		
1st larval stage.....	7	3	.....	1.32	.345
2nd larval stage.....	9	6	.....	2.13	.556
3rd larval stage.....	12	11	.....	3.47	.916
4th larval stage.....	15	16	17	5.91	1.15
5th larval stage.....	17	22	23	8.46	1.72
6th larval stage.....	18	26	27	12.4	2.20
7th larval stage.....	19	28	29	19.3	3.30
8th stage (adult).....	20	30	31	29.1	4.13

Width—distance between the lateral edges of the tergites.
Length—distance from forehead to tip of anal segment.
All the animals measured were males except possibly some females among those individuals of the first three larval stages where it was impossible to distinguish sex.

thus insuring very little, if any, evaporation. However, a few drops of water were added occasionally and moisture and other conditions were kept as natural as possible. Some of the receptacles were opened every day, others nearly as often, for observations and fresh air entered at these times. Later observations indicate that this exchange is not frequently necessary because some receptacles were not opened often but the animals appeared to thrive as well as others. *Euryurus* is therefore easily kept in captivity and breeds and thrives in the artificial environment described. A number reared in the laboratory survived during the summer and during most of the fall of 1925, at The Ohio State University. The humus

and small pieces of decayed sapwood, placed in the receptacles, were examined carefully for contaminating forms, such as other Millipedes, centipedes, mites, earthworms, eggs, insect larvae, pupae, etc., and those found were removed. However, enchytraeid worms, some earthworms, craneflies, thysanura, mites, ticks and a few beetle larvae were later found in some of the receptacles so the elimination was not complete. Adult males and females observed copulating and, in some cases males and females not pairing, were isolated in separate receptacles. In most of the jars the females laid eggs and these were permitted to hatch in the same receptacle with the adults. As soon as the larvae started emerging from the eggs, a number of the small specimens were placed in Petri dishes in order to observe their habits more accurately. An abundance of material was available for study. Observations of the larvae were continued through their metamorphosis, thus the larval stages in the life history were determined and certain other observations recorded.

In studying the development of the gonopods at least three individuals of each stage were used,—in most cases more—and the gonopods of each stage when possible were examined in the following ways:—(1) Many dissections of each of the different stages in the development were made, dehydrated, cleared and mounted on slides. In the earlier stages, especially, it was not possible to study the gonopods carefully without doing this. (2) The gonopods were dissected from a number of freshly killed individuals in stages seven and eight and drawn without mounting. (3) All the steps in the developing gonopods were also studied in place on freshly killed individuals.

Camera lucida drawings, made at different levels by focusing, were put together to indicate the form of the structures studied. There were variations but, in general, the pattern was nearly uniform. When possible the mounted structures were studied under the high power objective.

Photographs were taken of larval stages and the adult; of some incomplete and completed cocoons, which are hollow, somewhat spherical chambers in which ecydses of the larval stages occurs; of the cast chitin of an animal which had completed ecdysis from the last larval stage to the adult.

Synonymy and Distribution

Polydesmus erythropygus. Nov.

1839. Brandt, J. F. Note Relative a la classification Des Especies Qui Composent Le Genre Polydesmus.

Polydesmus erythropygus.

1841. Brandt, J. F. Recueil, 134.

Euryurus maculatus.

1847. Koch, System d. Myriap., 138.

Polydesmus (*Paradesmus*) *carolinensis*.

1859. Saussure, Linnea Entomologica XIII, 325.

Euryurus maculatus.

1863. Koch, Die Myriapoden. Bd. 1, 7 to III, fig. 8.

Polydesmus Subgenus *Paradesmus erythropygus*.

1865. Wood, Trans. Am. Phil. Soc. XIII, 218.

Euryurus erythropygus.

1888. Bollman, Notes on a Coll. of Myriapoda from E. Tennessee, Ann. N. Y. Ac. Sci. X, pp. 106-112.

E. erythropygus—Common in E. Tennessee (Beaver Creek), Proc. U. S. Nat. Mus., XI, pp. 339-342. Notes on a Coll. of Myriapods from Mossy Creek, Tennessee.

E. erythropygus—Common. Cat. of Myriapods of Ind. Proc. U. S. Nat. Mus., XI, pp. 403-410.

E. erythropygus—Abundant. Notes on the N. Am. Myriapods described by C. L. Koch.

E. maculatus Koch. Syst. Myr., 138, 1847 (? habitat); Die Myr., 1, 7, pl. 3, fig. 8, 1863. According to Peters *maculatus* is the same as *E. erythropygus* (Brandt).

Distribution of *Euryurus*

From the literature that was accessible *Euryurus* is known only from Africa and the United States of America. A list of this literature is included in the Bibliography.

Dr. C. L. Koch, ('63), reports the country unknown.

H. C. Wood, ('65), *Euryurus erythopygus* is found in Western Pennsylvania and Illinois.

Dr. R. Latzel, ('84), reports it for Africa and America.

Bollman, ('93), gives the following data concerning the habitat of this species:— (a) Common in Tennessee at Beaver Creek, Jefferson Co., East Mossy Creek. (b) Abundant in Indiana at Bloomington, Boswell, La Fayette, Kokomo, Westfield, Terre Haute, Greencastle, Mitchell, Salem, New Providence, Brookville, Wyandotte.

In 1924–1925, the writer found the animals abundant in southwestern Ohio, near Oxford, in Butler County.

DESCRIPTION.

The body is convex on its dorsal and ventral surfaces and in the adult is made up of twenty body segments besides the head. They can roll up into a spiral but not into a ball. The tergites are elevated in the middle, more so in the female than the male. The body segments, with the exception of the first, are entirely fused into a ring, that is, the tergites are fused with their appropriate pleurites and these with the appropriate sternites. This is characteristic of the *Polydesmidae*. The first sternum alone is free. The body is hard, the dorsal side smooth, shining and naked, with brilliant orange spots. There is a rather large semicircular orange spot on the posterior edge of each of the tergites. The orange color varies in intensity, in some it is deep orange, in some light.

This color bleaches out almost or entirely in alcohol or if allowed to dry. On each tergite olive-chestnut colored areas are arranged around the orange spots. The color becomes darker toward the maculae. The keels or lateral edges of the tergites are colored orange. These keels or edges of the body segments are very prominent, wing-like and powerfully developed and the prominent longitudinal ridges found on them bear the repugnatorial pores. These pores are found on the keels of segments 5, 7, 9, 10, 12, 13, 15, 16, 17, 18, 19 and are surrounded by long oval swellings on the dorsal side of the keels. The keels of the four segments next to the last and the first five behind the head are crowded together so that they slightly overlap each other.

The mandibles present on the side of the head project like cheeks. One pair of maxillae is present. They have united to form a well developed lower lip, the gnathochilarium. No maxillipedes are present.

The head is smooth, hard and shining and a rather deep dorso-ventral cross furrow was observed on the olive-colored forehead in the middle above the level of the bases of the antennae. The animal is eyeless. The antennae are short and are composed of eight antennal joints in adults.

In most individuals there is a well marked black, median line along the dorsum. This is especially noticeable in the larval stages before the pigment develops and in individuals of a slate color. In larval stages the margins of the lateral carinae appear faintly orange in the third moult before the

adult in some specimens. Gradually the color increases and the chestnut and olive and slate colors appear in the stage preceding the adult. The ventral side and the legs are dull yellow in color. After drying for a while or if preserved in alcohol or glycerine or a mixture of both, they become a yellowish brown color.

The legs are somewhat hairy but without special characteristics. The eighth pair of legs specially modified as gonopods are present on the seventh sternite of the male of all except the first three larval stages, in which they have not yet appeared. The paired openings of the vasa deferentia are found on projections located on the coxal joints of the second pair of legs. Genital structures (vulvae) are found in a somewhat similar position attached near the base of the second pair of legs in the female.

The anal segment is quadrate, trapezoidal and broad. There is an anal plate on either side of the anal opening. The anal scale is broad and rounded posteriorly. It is rather large and tapers and a few hairs project from its ends and sides. There is an orange spot on its posterior margin.

Some conclusions regarding differences between adult males and females.

1. Females were more numerous than males.
2. The legs of males are slightly longer than those of the females.
3. Females thicker dorso-ventrally than males.
4. Females slightly longer than males.
5. Females slightly wider than males.
6. Chestnut color of females often darker than that of males.
7. The longitudinal ridges along the keels of the males appear to be more prominent than on the females.
8. Females have thirty-one pairs of legs, vulvae developed on the second pair.
9. Males have thirty pairs of walking legs with sex organs opening on the coxapods of the second pair and the eighth pair modified into gonopods or copulatory organs.

Life History

(*a*) Description of copulation.

In copulation the male is usually above the female and with dorsal surface up and head bent over the anterior part of the female which is usually below with ventral side up in contact with the ventral side of the male. The anterior legs of the male are used to clasp the female, hooking over the keels or edges of the tergites. The gonopods enter the vulvae of the female.

(*b*) Observations concerning the eggs:

(1) Oviposition.

In most cases the females laid their eggs in cavities made by themselves a short distance below the surface of the soil. Under natural conditions the eggs have been observed in small cavities in much decayed logs.

(2) Numbers laid.

Under artificial conditions in the laboratory, in one case 526 eggs were counted. On April 18, 1925, while collecting, a single nest of eggs was found in a small cavity. The nest was brought in with extreme care, and found to contain 586 eggs.

(3) Size, shape, color, coating.

The eggs are very small and coated with a glutinous fluid which causes them to adhere in clusters. They are usually spherical, and greenish yellow in color, but some oval, some opaque and some brown eggs were found. The usual diameter of oval eggs was from .44 to .45 mm., and the length .53 to .534 mm.; the dimensions of the spherical ones .516 to .518 mm. by .520 to .524 mm.

(4) Constitution:

Myriapod eggs, according to Korschelt and Heider ('99, vol. 3, p. 219) "are very rich in yolk and are surrounded by a vitelline membrane and another structureless but firmer envelop, the chorion, which is apparently secreted by the genital ducts." This description may be applied to the eggs of *Eury-urus*. The egg envelop was observed when split and the young forms were about to emerge.

(5) Time of hatching:

(a) Laid October 4, 1924; hatched Nov. 8 (36 days).

(b) Laid October 31, 1924; hatched Dec. 17. (48 days.)

(c) Laid December 19, 1924; hatched Jan, 28, 1925. (41 days.)

Eggs collected in their natural environment and brought to the laboratory April 18, 1925, were hatched by May 16. (29 days.) Time of laying not known.

In one case not observed as closely as the above, a male and female were observed copulating December 17, 1924, and were placed in a separate receptacle. The eggs were not observed but sixty-five days later on February 19, 1925, individuals of the first larval stage were found. In another similar case sixty-eight days elapsed. In the latter case the weather was colder.

(*c*) Post-embryonic development.

(1) The stages, ecdyses, intervals between them and cocoon building.

Stages

The larvae of *Euryurus* apart from the smaller number of segments and lack of pigment in the earlier stages, does not differ greatly in form from the adult. The first larval stage possesses three pairs of legs. According to Korschelt and Heider ('99, vol. 3, p. 236), "The possession of three pairs of legs by the first larval stage brings about a striking resemblance to an insect larva..... This is, of course, merely an external resemblance, for, in the first place, the homology of the cephalic regions of the insects and the Myriapods (in respect of the number of segments utilized in the formation of the head), is still very doubtful, and further in the latter, one of the anterior trunk segments, usually the second, is, as a rule, devoid of extremities, so that the first three pairs of legs are distributed on four segments, whereas the thorax of the Insects, as is well known, consists of three segments, each possessing a pair of limbs."

In the post-embryonic development of *Euryurus* the additions are in the form of the double segments characteristic of the Diplopoda.

(Korschelt-Heider '99, Vol. 3, pp. 237-238) "The formation of new somites always takes place between the anal segment and that last developed (Latzel), and the formation of double segments is now proved to be due to the fusion of two of the originally distinct primitive segments (Heathcote.) The six-

limbed larvae has several other pairs of legs as rudiments beneath the integument. The number of these varies in different forms. It is characteristic of the terminal segment in the Diplopoda that no fusion takes place in it, and this is also the case with the four anterior segments (known as the thorax), and, apparently, fusion is also absent in the genital segment."

The post-embryonic development of *Euryurus*, as shown in the table given on page 26, is characterized by seven moults. Fig. 6 is a picture of the larval stages and the adult stage. A single pair of legs is found on the first, third and fourth trunk segments of all the stages, the second trunk segment lacks limbs in every case in *Euryurus*. Sexual maturity is reached in the eighth stage. Adults have not been observed to moult. Besides the single pairs of legs on the first, third and fourth trunk segments of the first larval stage, two truncated pairs of legs are found lying below the integument, belonging to the fifth segment and a single pair of the same kind the sixth segment. These limbs project freely after ecdysis. No intermediate sizes between the stages were found.

The post-embryonic development of *Euryurus* as observed by the writer, is similar to that of the genus *Polydesmus*, given by Drs. R. Latzel and O. vom Rath, except that for the third stage they have recorded observing ten pairs of legs for males and eleven pairs for females. The writer examined carefully sixty-six individuals of the third larval stage of *Euryurus*, and found all of these to possess eleven pairs of legs.

Fifty-six of these individuals examined were reared in the laboratory. On April 20, 1925, ten forms collected April 18, 19 , from their natural environment, were inspected and all of these had eleven pairs of legs. As females are more numerous than males in this species, there was the possibility that all the animals examined having eleven pairs of legs were females. Eight specimens, each having eleven pairs of legs, were isolated in a Petri dish in which soil had been placed, which had been carefully examined to make sure that no other *Euryurus* larvae were present. After ecdysis had occurred, two were found which had sixteen pairs of legs, this distinguishing them definitely as males and six were found possessing seventeen pairs of legs distinguishing them as females. This is conclusive evidence that all of the sixty-six individuals previously examined, were probably not females. Ten individuals of the third larval stage of *Oxidus* (*Paradesmus*) *gracilis*, another Polydesmid,

were examined and no individuals with ten pairs of legs were found. None of this species were reared to the next stage.

Eggs of *Polydesmus serratus* were collected under natural conditions (April, 1925), and brought in and hatched in the laboratory. Eight individuals reaching the third larval stage were carefully examined by Dr. Williams and myself, and all eight were found to possess eleven pairs of legs. These were isolated in a glass container and brought to the Lake Laboratory and there reared to the next stage, in which the first individual examined had sixteen pairs of legs, thus distinguishing it as a male.

Ecdysis.

Euryurus attains its full sexual character after seven moults, in each of which the chitinous cuticle is entirely thrown off and replaced by a new one secreted by the epidermis or hypodermis just under it. The exoskeleton is shed after each larval stage, but has not been observed to be shed by adult animals. Ecdysis is performed at intervals in the larval stages.

TABLE SHOWING THE SHORTEST AND LONGEST TIMES OBSERVED FOR THE INSTARS OR STAGES BETWEEN ECDYSES.

1st Instar	5 to 14 days
2nd Instar	14 to 20 days
3rd Instar	22 to 24 days
4th Instar	26 to 30 days
5th Instar	31 to 34 days
6th Instar	41 to 41 days
7th Instar	44 to 47 days
Hatching of Eggs	29 to 48 days
Lengths of life history	212 to 258 days

The ecdyses of individuals in cocoons were followed to find out if possible how ecdysis occurs and to look for intermediate steps in the development of the gonopods between stages three and four and seven and eight.

To determine whether moisture is a factor in the length of time for ecdysis, an experiment was performed in which the temperature was fairly uniform but moisture was varied. (a) In one Petri dish individuals of the first larval stage were placed in a rather moist environment. (b) In another dish similar individuals were placed in a considerably drier environment. Animals in the conditions designated in (a) moulted in from 6–8 days. Animals in (b) moulted in from 13–14 days. These results indicate that it takes a longer time for ecdysis

under rather dry conditions. With these cases and others observed other conditions such as temperature and confinement may have also modified the intervals so that they may vary from those occurring under natural conditions.

METHOD OF ECDYSIS DERIVED FROM STUDYING SOME CAST SKINS OF LARVAL STAGES.

Fig. 7 is a picture of the cast skin of a female which had moulted from the last larval stage to the adult stage. The old chitin had split down the mid-ventral line and also somewhat laterally, just above the attachment of the legs on one or both sides. The dorsal surface seemed intact in this and in other casts observed. The cast was disarticulated at the junction of the head and first segment and the animal must have crept forward, causing the anterior end to crowd together somewhat. This was also noticed in other casts observed.

Cocoon Building.

The larvae of each stage build their cocoons as follows:— Small bits of much decayed wood, or earth are moistened with a sticky fluid, presumably secreted by the salivary glands.

The materials used are worked up with the jaws and front legs and when of a suitable size are placed together. The completed cocoons are shaped somewhat like a hollow sphere (Fig. 9.) The inside is rather smooth and even and the outside is rough. The shape and size of the materials of which it is composed can be readily discerned. A small stack or bluntly rounded chimney-like projection is made and closed up at the top. Indicated by the arrow in Fig. 9. Fig. 8 is a photograph of three cocoons in the process of construction by forms of the seventh larval stage. The one slightly to the left of the center is the result of the work of one individual for about one day and represents the base. The animal was continuing this construction just before this picture was taken. As soon as disturbed it disappeared. The small bits of materials are put into place from the inside and the individuals work around. The other two cocoons in the picture are much nearer completion than the one described and represented from two and one-half to three days work. The animal at the base of the upper one on the right was working inside and when interrupted to take the photograph it made a hasty retreat for a millipede, hence the somewhat blurred picture of it. The

cocoons in the photograph were constructed on the upper surface of pieces of rotten wood lying on top of the other material in the glass receptacles and were photographed in place. Some animals in the fifth, sixth and seventh larval stages built their cocoons on the side of the receptacles above the surface of the contents. Fig. 9 is a photograph of two completed cocoons and the animals are enclosed in them. These were built by individuals of the last larval stage. Three and one-half to four days were required for their construction. Dimensions of the upper cocoon:

Width at bottom where attached = 18mm.
Width of the chimney-like projection = 5 mm.
Height of the whole cocoon, including the chimney = 21 mm.

Notes on the time it takes to build the cocoons in which the last larval stages moult:

A. (1) A female started construction Jan. 12, 1925.
(2) Finished on Jan. 16.
(3) Emerged from the top March 3. (47 days.)
The chimney-like projection was broken off.
Measurements of the cocoon:—
Width at bottom = 17mm.
Height to the projection = 13.5 mm.
Height of the projection = 4.5 mm.
Width of the projection = 5.0 mm.

B. Cocoon started by a male on Jan. 28, 1925, was completed Jan. 31. This was built along the side of a glass receptacle a short distance above the level of the contents.

Most of the cocoons built by the other larval stages were built below the surface. The animals are very helpless a short time after they close up their cocoons. If a cocoon is opened and the animal disturbed when in the midst of ecdysis no motions can be perceived, indicating that they are absolutely helpless during this process. Near the completion of ecdysis motion is apparent. Presumably the cocoons are built for protection. Three individuals in the midst of ecdyses from stage three to four were observed to be eaten by a beetle larva.

On April 19, 1925, cocoons and larval stages of *Euryurus* were found in their natural environment.

The Development of the Gonopods.

The gonopods of the male are modified from the eighth pair of legs on the seventh body segment. With naked eye or with low magnification in all the individuals of the third larval stage examined, the eighth pair of legs appeared to be

most appreciably smaller or otherwise different from the walking appendages. With higher powers of the microscope a measureable difference was found in some individuals after dissecting and mounting the eighth and ninth pairs of legs. In one typical specimen the eighth pair of legs were found to be .559 mm. long and the ninth pair .576 mm. long. It is presumed that the individual from which these were dissected was a male.

In another specimen the eighth pair of legs were .568 mm. long and the ninth pair .571 mm. long. The individual from which these were dissected might possibly have been a female.

In *Euryurus*, according to observations, the modification of the male gonopods, which are found in the place of the eighth pair of legs, appears first in the fourth larval stage. Following are the steps found in the development of the gonopods, with description and measurements of each.

First Step.

On the fourth larval stage in place of each of the eighth pair of legs of the preceding stage, a single joint is found outlined by an oval bounding line. (Fig. 1.) Measurements of the joints = .077 mm.; heighth = .043 mm.

Second Step.

In the fifth larval stage two joints were found in place of the one found previously. This time the two pairs of these joints are placed symmetrically in a small oval disc. (Fig. 2.) The joints could not be dissected from the disc because of their delicacy so the whole sternite and the ninth pair of legs were mounted. Measurements: Length of oval disc = .292 mm.; width, .112 mm.; first joint, length = .103 mm.; width = .065 mm.; second joint, length = .073 mm.; width = .052 mm.

Third Step.

In the next larval stage, three joints representing each appendage were found in a larger oval disc. (Fig. 3.) Measurements:—length of oval disc = .361 mm.; width = .206 mm.

First joint	*Second joint*	*Third joint*
Length = .146 mm.	Length = .138 mm.	Length = .103 mm.
Width = .141 mm.	Width = .123 mm.	Width = .060 mm.

The line across the oval disc, projecting slightly on either side, probably represents a boundary line between sternites.

Fourth Step.

In the last larval stage, each appendage shows three joints as before, but considerably changed and enlarged and for the first time free from the sternite and lying in an oval opening in it. (Fig. 4.) The dotted lines outlining the first joints indicates that the greater part of these lies in a cavity under the sternite. Measurements: length of oval opening = .705 mm.; width of oval opening = .370 mm.

First joint	*Second joint*	*Third joint*
Length = .215 mm.	Length = .327 mm.	Length = .292 mm.
Width = .202 mm.	Width = .146 mm.	Width = .258 mm.

The gonopods shown in 4B were dissected from a freshly killed specimen and drawn without mounting. Divisions were observed on the basal joints and are indicated by lines. The shaded areas indicate depressions in the secondand third joints. There are cavities opening to the outside designated by a and e. There seemed to be a cavity or hollow space inside the proximal joint of each gonopod when examined from a dorsal view.

In the drawings of mounted gonopods studied under a higher magnification more details could be observed. (Fig. 4A.) The third or distal joint appears to be attached only at the outer edge. In one case examined, the terminal joint showed the structure as indicated by the distal joint (d. j.) on the left gonopod. (Fig. 4A.) A comparison with the adult gonopods, Fig. 5 shows a similarity. Other similar cases were observed. Thus the terminal section of the gonopod is differentiated from the third joint by the breaking away of the wall on the inner proximal corner and then, by straightening somewhat, produces the curved adult distal joint. The proximal joint is large and represents the coxal joint of the appendage enlarged and differentiated. Whether the other joints have been cut off distally from it and certain structures of the adult gonopods in turn developed from these, or the distal joint of the three represents the first step in the development of the gonopod and the other joints have appeared one after the other behind it, is not determined.

The breaks in the chitin shown in Figures 4A and 4B must be in some way connected with the forming of the distal joint which later, by straightening and going laterally, will produce the curved end of the male organ.

Fifth Step.

No intermediate conditions during ecdysis between stages seven and eight were found. Sexual maturity is reached in the eighth stage and is accompanied by the complete copulating appendages as shown in Figures 5, 5A, 5B. The adult gonopods are curiously modified. At the base of each gonopod a large joint is found, known as the coxa copulativa. Dimensions:— Length = .989 mm.; width, = .654 mm. A transverse hook is attached to the inside of each of these, the purpose of which is probably for holding. In some gonopods mounted on slides this appeared tubular. On the concave side of the distal joint of the much curved gonopod is found a hairy elevation, pulvillus piligerus, for the reception of sperm. Immediately distal to this is located a blunt spine. A structure which looks like a tube starts below its proximal end and passes to the end of the long needle-like projection on the terminal curved section of the gonopod. In an endeavor to learn whether this was a tube some dissected gonopods were placed in stain. The stain did not penetrate into this, possibly hindered by capillarity or perhaps there is no passage. In general, the middle joint is narrow as compared to the other two and in some cases is wedge-shaped so that sometimes the proximal and distal joints touch each other on the outer edge. There is a terminal section which curves inward like a swan's neck and is distally bifid. "The forked fingers of these gonopods are long and needle-like and somewhat twisted." (Koch)

Numerous hair-like projections are found on the gonopods as indicated in Fig. 5A.

From the top of the second joint to the tip of the terminal section = 1.46 mm.

The oval opening through which the gonopods project has a rather high sharp edge. Dimensions:— width = .903 mm.; length = 1.25 mm. Specimen 1.

Specimen 2:— width, = .928 mm.; length, 1.29 mm.

Summary of the steps in the development of the Gonopods.

(1) Individuals of the third larval stage and eleven pairs of legs, with a somewhat reduced eighth pair of legs were thought to be males, the others females.

(2) In the next moult the eighth pair of legs have disappeared and in their place two very small joints appear.

(3) The fifth larval stage shows a small oval disc with two joints of each of the gonopods outlined.

(4) The next moult shows three joints on each side in a somewhat larger oval disc.

(5) In the last larval stage these appendages are free from the sternite and lie in an oval opening in it.

The terminal sections of the gonopod differentiate from the third joint by the breaking away of the wall on the inner proximal corner and then by straightening somewhat to produce the adult distal joint.

Proofs that the gonopods are modified from the eighth pair of legs:

(a) Commencing in the fourth stage the males have one less pair of legs than the females. The eighth pair of walking legs is missing in males.

(b) The males in stage three possess eleven pairs of legs the same as the females. In the moult between stages three and four, the eighth pair is lost and the rudiments of the gonopods appear in the fourth larval stage.

SUMMARY.

I. Differences between adult males and females.

1. Females were slightly longer, wide, thicker and more numerous than males.
2. The legs of the males are slightly longer than those of the females.
3. Females have thirty-one pairs of legs with vulvae attached to the second pair.
4. Males have thirty pairs of walking legs with sex organs opening on the coxopods of the second pair of legs and the eighth pair of legs modified into gonopods or copulatory organs.

II. Post embryonic development.

The post-embryonic development of *Euryurus* is characterized by seven moults, with the addition of segments and pairs of limbs as shown in the table on page

III. Ecdysis.

1. Euryurus attains its full sexual character after seven ecdyses which are performed at rather short intervals and in cocoons.
2. The time required for ecdysis increases with each later larval stage.

IV. Gonopods.

The gonopods undergo a gradual progression and development from the fourth larval stage on to the adult stage.

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FIG. 1

FIG. 2

FIG. 3

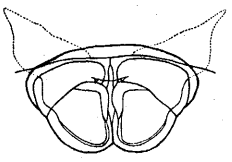
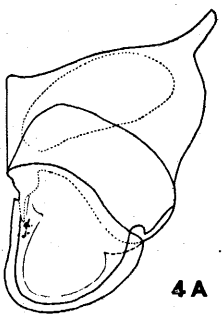
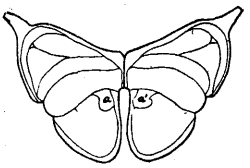


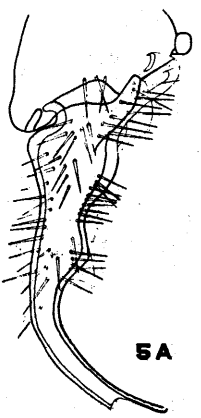
FIG. 4



4A



4B



5A

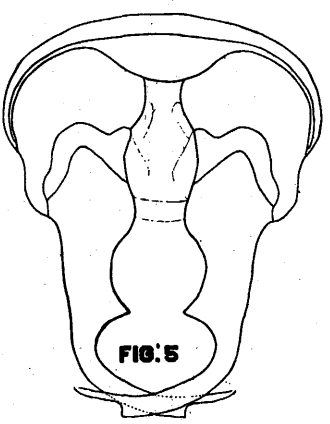
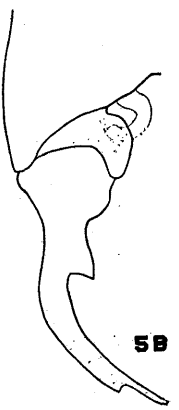


FIG. 5



5B

Each of the stages in the development of the gonopods was drawn to scale and shows the development as it progressed. The drawings, although necessarily slightly schematic, are in no sense mere diagrams, but are attempts to represent as closely as possible the actual appearance of the objects.

Unless otherwise specified, drawings from ventral side.

Fig. 1. The single joints or rudiments of the gonopods of a male of the fourth larval stage in place of the eighth pair of legs.

Fig. 2. Joints of the gonopods shown in the oval disc of an individual of the fifth larval stage.

Fig. 3. Joints of the gonopods of the sixth larval stage fastened to the oval disc.

Fig. 4. Joints of the gonopods in place, now free from the sternite, lying in an oval opening in it. Seventh larval stage.

Fig. 4A. Drawn from mounted gonopods, dissected from the last larval stage. Detailed drawing of left gonopod.

Fig. 4B. Gonopods dissected from a freshly killed individual of the last larval stage.

Fig. 5. Adult gonopods in place in a freshly killed specimen and the oval opening through which the gonopods project.

Fig. 5A. Right adult gonopod showing the numerous hair-like projections, and transverse hook attached to the coxa.

Fig. 5B. Dorsal view of right adult gonopod dissected and drawn from a freshly killed individual.

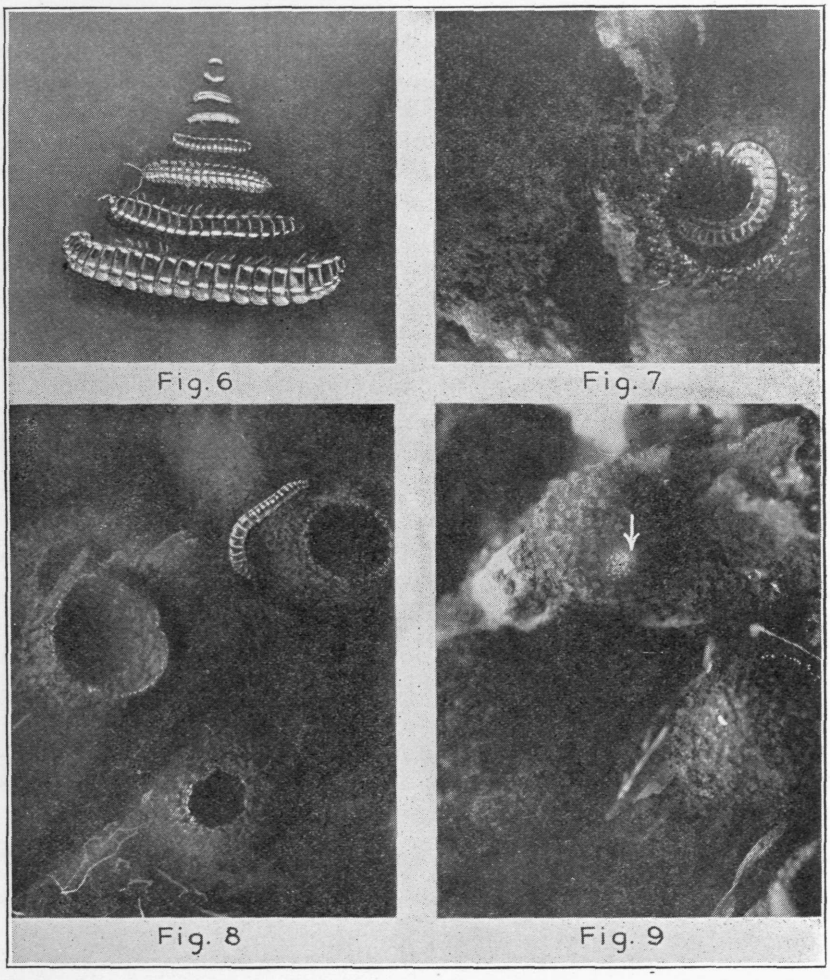


Fig. 6. Photograph of the larval stages and adult of Euryurus.

Fig. 7. Photograph of the cast "skin" of a female individual which has moulted from the last larval stage to the adult. The upper part of the cocoon was removed.

Fig. 8. Three cocoons in the process of construction. Two nearly completed and one recently started.

Fig. 9. Photograph of two completed cocoons. The arrow indicates the characteristic chimney-like projection built on top of these.